# Remarks

## General

The specification has been amended editorially to correct typographical errors.

Claim 1, 2, 4 to 7, 10, 12, 14 to 18, 20, 22 to 26, 28, and 29 are pending. Claim 3, 8, 9, 11, 19, 21, and 30 have been cancelled. Claim 13 and 27 have been amended to clarify the logical relationship among elements. The dependent claim 26 incorporates all the subject matter of the parent Claim 17, and Claim 22 which provides the proper antecedence for the "said substrate".

## Background information – Diffractive grating and Fresnel zone plate are different optical devices

Prior to discussing the objection to rejections, the Applicant will first provide the essential background information distinguishing the novelty of the present invention and its unobviousness over the cited references.



Diffraction grating and Fresnel zone plate are different optical devices. They have very different structural designs, and possess substantially different optical properties.

### – *Diffraction grating*

A diffraction grating is a *linear* optical device consisting of a number of *periodic* reflecting or transmissive surfaces. The reflecting surfaces, as shown in Figure 1a, are usually in the form of elongated ribbons. These elongated ribbons are arranged one next to the other along the x-direction in such a way that the longer sides of the ribbons are parallel to each other. Therefore along the x-direction, a *periodic structure* with a periodicity W = W1 + W2 is formed, where W1 and W2 are the widths of Element 1, and Element 2 respectively.

Referring to Figure 1b, the most important feature of a diffraction grating is that when the grating is illuminated in the normal direction by a plane wave 4, the diffraction grating generates +1 order diffracted *plane wave* 6 and –1 order diffracted *plane wave* 8 at an angle $\theta$ as determined by the grating equation:

$$W\sin(\theta) = n\lambda$$

where $\lambda$ is the wavelength of the illumination, and n is the diffraction order.

### – *Fresnel zone plate*

A Fresnel zone plate is a *symmetrical circular* optical device consisting of a series of *concentric circular* zones as shown in Figure 2a. The widths of the

zones *are not equal* as in the case of diffraction gratings. Instead, the radii of the zones are determined by the zone plate equation:

$$R_n = \sqrt{n\lambda F + \frac{n^2\lambda^2}{4}}$$

Where $R_n$ is the radius of the $n$th zone, $\lambda$ is the wavelength of the illumination, and $F$ the focal length of the zone plate.

The most important feature of a Fresnel zone plate is that it is a *lens*. Accordingly, it is capable of forming images just as regular lenses. In particular, when a zone plate is illuminated in the normal direction by a plane wave, it forms a *focal point* along its optical axis at a distance of $F$ from the center of the zone plate, as shown in Figure 2b.

The fact that a zone plate is a lens has been clearly documented in many references such as the article by R.W. Wood (R. W. Wood, *Philos. Mag*. V45, 51, 1898, which is included in the original IDS filing). In contrast, a diffraction grating can not function as a lens. Fresnel zone plates and diffraction gratings are *different* optical devices.

**The Objection to the claim rejection as being anticipated under § 102 by Bloom et al**

Claims 1-4, 14-16, 17-20, 22-24, and 28-29 were rejected under 35 USC 102(b) as being anticipated by the patent issued to Bloom et al (PN. 5,311,360).

The diffractive modulator taught by Bloom et al is based on *diffractive gratings*. The diffractive modulator comprises a plurality of equally spaced apart *grating elements*, each of which includes a light reflective planar surface. The elements are arranged *parallel* to each other with their light reflective surfaces parallel to each other (PN. 5,311,360, column 3, line 32 – 37). In an individual grating, all the elements are of the *same dimension* and are arranged *parallel to* one another with the spacing between adjacent elements equal to the beam width (PN. 5,311,360, column 5, line 26 – 29). The diffracted beams in the diffracting state remain as *plane waves* (PN. 5,311,360, 28, Figure 4). Furthermore, the commercial name for Bloom's diffractive grating modulator is called Grating Light Valve or GLV (Silicon Light Machines, CA, USA), undoubtedly further identifying that Bloom's diffractive modulator is based upon diffractive gratings.

In contrast, the wave modulating device claimed by the Applicant comprises of a very different optical element, *the Fresnel zone plate,* serving as *a lens*. The reflecting surfaces on the zone plate are in the form of *concentric circular* reflective zones with the radii of the zones determined by the zone plate equation. The wave modulating device produces a *focused beam* in the diffracting state with its focal point being at a distance *F* from the center of the zone plate. Such a result is *not physically possible* with Bloom's diffractive grating modulator.

In many lithographic or imaging applications, focused beams are required. U.S. Patent Application 10/708,778, filed by the Applicant on March 24, 2004, describes many examples of such applications. The wave modulating device disclosed by the Applicant can perform both the *modulation* and *focusing* functions in a single device. This is to be contrasted with the Bloom's diffractive grating modulator which is not capable of focusing beams. This problem of Bloom's diffractive grating modulator is clearly shown by D. Gil et al (G. Gil et al, *Journal of Vacuum Science and Technology* B, Vol. 20(6), p2597, Nov/Dec 2002, which is included in the original IDS filing). In order to produce

focused beams, D. Gil et al had to use a lens array placed after the Bloom's diffractive grating modulator, as shown in Figure 1 of the reference.

With regard to claim 17, 18, 20, and 29, Bloom et al did not teach how a 2D array based on the diffractive grating modulator would be constructed and used. In fact, such a 2D array is inoperative. Attempts for implementing such 2D arrays based on Bloom's diffractive grating modulator *failed commercially* as shown by Attachment #1. Therefore, only 1D arrays of diffractive grating modulators are commercially available.

The reason for the failure is, as indicated in Figure 3a and Figure 3b, that only the *small central region* of the *long* grating elements, when deflected, are sufficiently flat to be used as gratings. The remaining large regions of the long grating elements are merely used as *supporting beams*, and can not be used as reflecting surfaces. When such diffractive grating modulators are arranged into a 2D array, the usable region (fill factor) of the 2D array, as shown in Figure 3b, is so small that it renders the 2D array unusable. Chapter 20.4.3.4 of the Attachment #2 provides detailed discussion of this particular issue.

In contrast, the wave modulating device claimed by the Applicant has a symmetrical design with a fill factor larger than 78%. Therefore, a 2D array of the wave modulating devices is practical, and overcomes the problem faced by Bloom's diffractive grating modulators.

The pending claims 1-2, 4, 14-16, 17-18, 20, 22-24, and 28-29 contain limitations and elements not disclosed by the patent issued to Bloom et al (PN. 5,311,360), and therefore overcome the rejection over the reference. It was also entirely unexpected that such exceptional capabilities of being able to perform both the modulating and focusing functions could be obtained in a diffractive grating modulator. Reconsideration of this rejection is requested.

**The objection to claim rejection as being unpatentable under §103 over the patents issued to Bloom et al and Greywall**

Claims 5-13 and 25 were rejected under 35 USC 103(b) as being unpatentable over the patent issued to Bloom et al (PN 5,311,360) in view of the patent issued to Greywall (PN. 5684631).

Claims 5-7, 10, 12, 13, and 25 are dependent claims. They are patentable for the same reasons given with respect to their parent claims. They are even more patentable because they add more limitations. Reconsideration of this rejection is requested.

**The objection to claim rejection as being unpatentable under §103 over the patent issued to Bloom et al**

Claims 21, 26-27, and 30 are rejected under 35 USC 103(a) as being unpatentable over the patent issued to Bloom et al (PN. 5,311,360).

Claims 26 and 27 are dependent claims. They are patentable for the same reasons given with respect to their parent claims. They are even more patentable because they add more limitations. Reconsideration of this rejection is requested.

## Conclusion

For all the above reasons, the Applicant submits that the specification and claims are now in proper form, and the claims all define patentably over the

prior art because that the present invention contains limitations and elements not disclosed by the prior art, and that the present invention provides results that were unexpected and are not possible by the prior art. Therefore, the Application submits that this application is in condition for allowance. Notice of Allowance is requested.

### Conditional request for constructive assistance

The Applicant has amended the specification and claims of this application so that they are proper, definite, and define novel structure which is also unobvious. If, for any reason that this application is not believed to be in full condition for allowance, the Applicant respectfully requests the constructive assistance and suggestions of the examiner pursuant to M.P. E. P. §2173.02 and §707.07(j) in order that the undersigned can place this application in allowable condition as soon as possible and without the need for further proceedings.

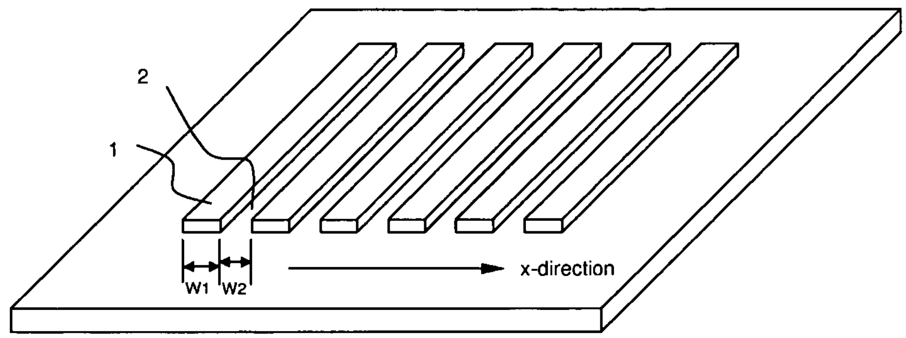


Figure 1a. A perspective view of a diffractive grating consisting of the repetitive elongated Element 1 and 2. The total width of the 2 elements W1 + W2 = constant.

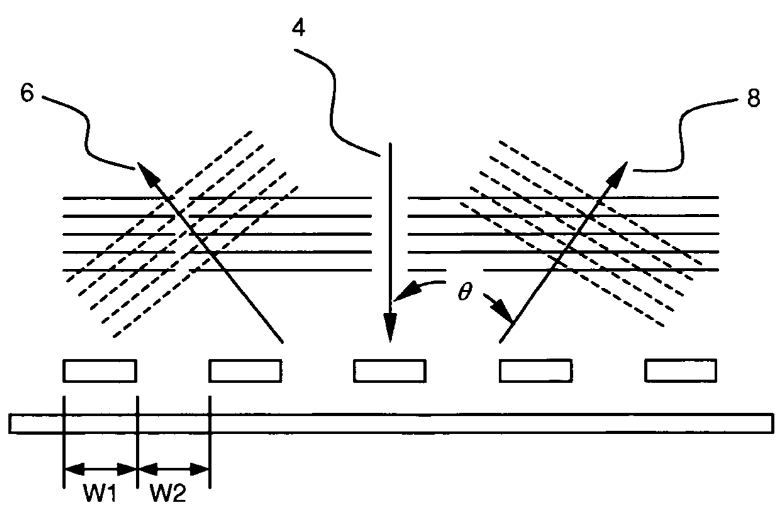


Figure 1b. A diffractive grating diffracts the incoming wave 4 into +1 order plane wave 6 and -1 order plane wave 8.

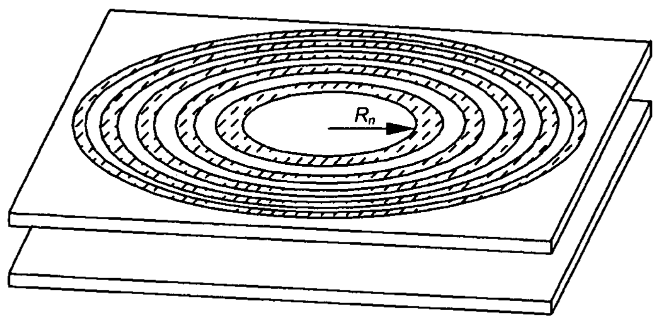


Figure 2a. A Fresnel zone plate where $R_n$, the radius of the $n$th zone, is determined by the zone plate equation.

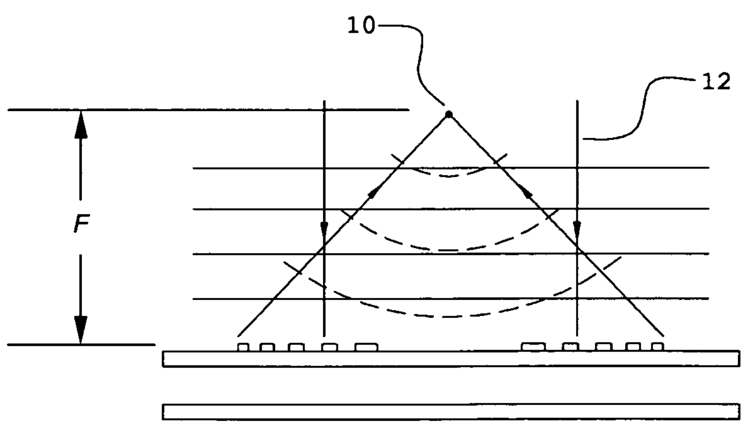


Figure 2b. A Fresnel zone plate functions as a lens and focuses the incoming wave 12 into a focal point 10. $F$ is the focal point of the zone plate.

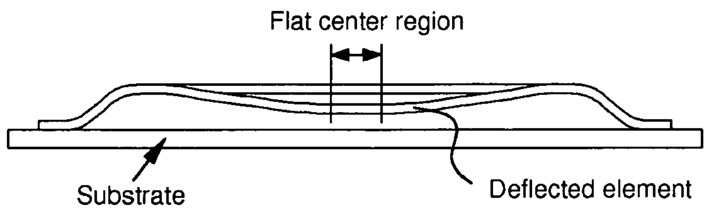


Figure 3a. A diffractive grating modulator in the deflected state. Only the small central region of the deflected element can be used for diffracting waves.

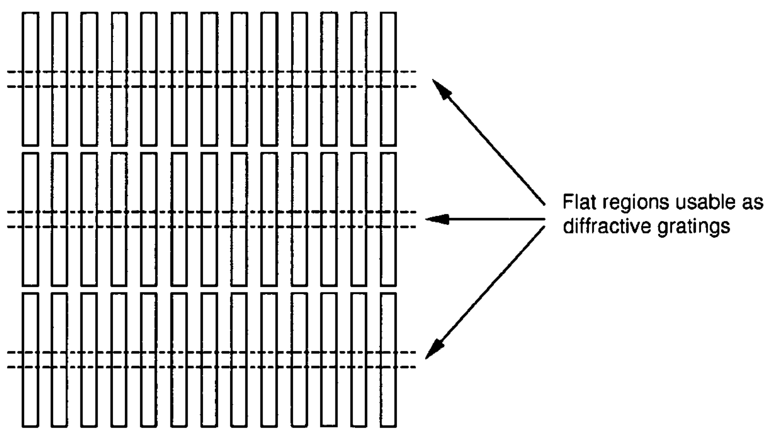


Figure 3b. Top view of an example two-dimensional diffractive grating modulator having three rows of linear diffractive grating modulators. Only the small central flat regions can be used for diffracting waves, therefore severely reducing the fill factor.

Very respectfully,

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Date: 2005 August 27

Inventor's Signature: Baokang Bi

## Attachments

Attachment #1:

*Growing pains beset miniature-display industry,* written By David Lieberman, http://www.eetimes.com/news/97/966news/growing.html. The relevant paragraph is underlined.

Atachment #2:

Chapter 4.20.3.4, *Microsystem Design*, edited by Stephen D. Senturia, Kluwer Academic Publisher, Boston, 2000

# Growing pains beset miniature-display industry

*By David Lieberman*

SAN JOSE, Calif. -- The nascent market for miniature displays -- a.k.a. display chips -- is experiencing some growing pains. Entering the market with an approach whose most distinguishing characteristic is its lack of novel technology, startup S-Vision hopes to clear the hurdles to volume production that have bedeviled some developers of more exotic mini-display designs. One of those companies, Silicon Light Machines Inc. (Sunnyvale, Calif.), recently laid off about a third of its staff in a redirection of its effort to bring its Grating Light Valve technology to market.

Targeting the market for high-resolution projection displays, S-Vision (San Jose) is sampling preproduction SVGA (800- x 600-pixel resolution) screens on a build-to-order basis, with volume production scheduled to kick off in the fourth quarter. The initial recipients of the company's Micro LCDs are primarily projector companies, with a few monitor companies and PC companies in the mix.

Like many other manufacturers of mini displays, S-Vision relies on liquid-crystal-on-silicon (LCOS) technology. But its reflective-display technology is based on conventional twisted-nematic (TN) LC material and CMOS silicon.

By contrast, other mini-display makers -- such as Silicon Light Machines and Texas Instruments Inc. -- are using exotic materials or such novel technologies as micro-electromechanical systems (MEMS). S-Vision sees pitfalls to that approach.

"MEMS displays have a custom process, and the guys who are putting down PDLC [polymer-dispersed LC] have trouble with contrast ratio and need higher voltage; they can't use 3.3 or 5 V," said Ray Pinkham, strategic marketing manager at S-Vision.

Pinkham acknowledged that TN-on-CMOS "might not be the ultimate performance you can conceive of, but it takes the path that leverages off the momentum in the industry [behind] CMOS and TN LC, which virtually all the LCDs use. Other approaches will have to develop step by step; our approach leverages off what's already going on."

That's "a sensible approach, a low-risk approach, and it should be a relatively straightforward path to at least making something that will work," said Chuck McLaughlin of the McLaughlin Consulting Group (Menlo Park, Calif.). Labeling the S-Vision strategy "a long-overdue technological thrust," McLaughlin observed that "everybody's been been trying all this really exotic stuff, but nobody has bet the farm on [TN LC and CMOS]. It may not result in the very best display -- maybe not be as fast as ferroelectric, for example -- but it's got to be very close."

Others disagree. David Mentley, director of industry research at Stanford Resources (San Jose, Calif.), said it's hard to discern what the "unique selling proposition" is for S-Vision's Micro LCD. Citing pending patents, the company declined to discuss the particulars of what it considers its unique selling proposition: an optical architecture that it claims will beat the competition in contrast and brightness while allowing less-expensive optical components to be used.

Nonetheless, some of S-Vision's competitors concede they have faced higher-than-expected hurdles to implementation. "Truthfully, things hadn't been going as fast as we'd hoped, say, a year ago," said Rob Corrigan, vice president of marketing at Silicon Light Machines (SLM), which burst onto the scene in September. "But we've now eliminated the issues we were bumping into, and the orientation for

the company is now 100 percent product development rather than research."

SLM's Grating Light Valve is a reflective MEMS display -- an approach whose manufacturability has yet to be proven. The Digital Micromirror Device, produced and marketed by Texas Instruments (Dallas), is also a reflective MEMS technology.

TI kicked off DMD production in April 1996 after having poured years and substantial sums into the technology's development. But the company has had a tough time ramping the product to volume.

"We're not happy where we are with DMD cost and overall manufacturing yields at this point," acknowledged Sherel Horsley, senior vice president of marketing for TI's Digital Imaging Group, speaking at a mini-display roundtable in May.

Corrigan of SLM, on the other hand, said that his company's reflective-MEMS effort is "rockin' and rollin' " and that "things are going quite well." But the company did make some adjustments recently after taking stock of the effort, he acknowledged. "A few months ago, we recognized that there was a more straightforward architecture that in some respects represented a shorter path to market for us, and it meant we needed fewer people developing custom silicon-processing technology."

SLM, unlike some other startup display makers, has been doing its own silicon processing, primarily at Stanford University's Center for Integrated Systems. "We'd intended all along to leverage the existing silicon infrastructure," Corrigan said. "But we found that to maintain process controls and really refine repeatability and precision into the runs, we would have had to more or less set up a dedicated silicon processing system," even though the technology uses "standard [semiconductor-manufacturing] equipment and materials."

Corrigan said the redesign removes the need to "own and operate dedicated equipment by changing pixel design and process flow to simplify things. The flow is now entirely CMOS-compatible wafer processing up to a few steps at the end, for which we're building a small clean room here. So we put an RFQ out on the street to a few local foundries in the Bay Area and got several responsive bids. We've picked one and are now doing most of our silicon processing there.

"As a result, there's now a very limited amount of processing we have to staff."

The upshot has been a layoff at the small startup. "It wasn't fun going down from 31 [employees] to 20, but it was the right thing to do," Corrigan said. "But we're still hiring in other areas. We're still looking for people on the systems side -- electronics and optics.

"The transition went as smoothly as one could hope. It's just one of those adjustments you make, but it doesn't represent anything more than that."

Unconfirmed reports have surfaced that SLM has given up on making an X-Y matrix of MEMS for a direct-view display and that it will now focus on making only a linear array. One source, who asked not to be named, said the company's current plan "is to make a projection device that consists of laser-light sources and a horizontal or vertical GLV array that's mechanically scanned in the other direction. That's probably more dependent on finding cost-effective laser-light sources than it is on the array."

Corrigan would say only that SLM has "never announced specific product intentions, so it's hard to comment on changes in products we haven't announced. But we've got parts running in the labs, and the yields look astounding. Confidence right now is at an all-time high."

Projection-display systems -- not head-mounted displays -- may be the most appropriate target for the emerging mini displays. "The only people using this [miniature] display stuff for HMDs have all gone belly up -- Forte and Virtual I/O," said Roger Stewart, director of the solid-state-display laboratory at Sarnoff Corp. (Princeton, N.J.).

The electronic-projector market, by contrast, is thriving. And the next big thing in projectors, according to Gil Miller, product marketing manager at projector-market leader In Focus Systems Inc. (Wilsonville, Ore.), is likely to be a reflective display technology like S-Vision's. "I don't know which [technology] it will be," he said, "but it probably won't be TI's DMDs, given the yield problems."

"Projection is a big market [for miniature displays], proven by TI's DMDs and the 1.3-inch polysilicon LCDs," said Bruce McWilliams, S-Vision's president and chief executive officer. "And that market is very much looking for a good solution for things like SXGA [1,280- x 1,024-pixel] and HDTV [above 1,000-line] formats. Maybe

our story isn't the sexiest technical thing, but it seems like the obvious approach for chip-based displays."

Indeed, the company has gone as far as to put together a beta projector using its displays, and it claims the approach has already snagged a customer. Sales manage Al Davis said S-Vision signed an agreement in May "with a major distributor of projection systems to deliver an XGA [1,024- x 768-pixel-resolution], 1,000-lumen projector."

Preproduction OEM projectors will sample early in the fourth quarter. S-Vision expects its distribution partner to be shipping projectors to end users before the year is out.

The Micro LCDs are now being run on 6-inch wafers at two unnamed foundries, yielding a maximum 50 displays per wafer. A move to 8-inch wafers is in the works that would boost the potential yield to 80 displays.

S-Vision has a small back-end LCD operation running in Twinsburg, Ohio, and has begun building a larger facility there.

Attachment #2



*ABOUT THE COVER*

ıe author gratefully acknowledges the cover photograph by Felice Frankel, :tist in Residence at the Massachusetts Institute of Technology and coauthor *On the Surface of Things: Images of the Extraordinary in Science.*

ıis particular image, taken with Nomarski optics, presents a wafer-bonded ezoresistive pressure sensor. It is fabricated in the sealed-cavity process :veloped by Professor Martin Schmidt of the Massachusetts Institute of Tech-ılogy with his graduate students, Lalitha Parameswaran and Charles Hsu. ıe piezoresistors are clearly visible, and the slight contrast across the central aphragm region shows that the diaphragm is actually slightly bent by the essure difference between the ambient and the sealed cavity beneath.

# MICROSYSTEM DESIGN

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**KLUWER ACADEMIC PUBLISHERS**
**Boston / Dordrecht / London**

Figure 20.19 illustrates the procedure. If we assume a tensile (positive) stress $\sigma_n$ in the nitride prior to release, and a compressive stress $-\sigma_a$ in the aluminum prior to release, then bond the two layers together and release them, the interface moves to the right by an amount $\delta$. To find delta, we require that the tension be equal in the two parts of the beam. This leads to

$$\delta = \frac{L}{2}\frac{\sigma_a h_a p(1-p)}{E_a h_a(1-p) + E_n h_n} \qquad (20.48)$$

From this, the stress in the uncoated nitride is

$$\sigma_{n,final} = \frac{E_n h_n \sigma_n + pE_n h_a \sigma_a + (1-p)E_a h_a \sigma_n}{E_n h_n + (1-p)E_a h_a} \qquad (20.49)$$

and the final tension in the beam is then $W h_n \sigma_{n,final}$. Using this result, Payne calculates the Rayleigh-Ritz resonant frequency as

$$\omega = \frac{\sqrt{10}}{L}\left[\frac{h_n\left[E_n h_n \sigma_n + pE_n h_a \sigma_a + (1-p)E_a h_a \sigma_n\right]}{\left[E_n h_n + (1-p)E_a h_a\right]\left[h_n\rho_n + p^3\left(\frac{3p^2}{8} - \frac{15p}{8} + \frac{5}{2}\right)h_a\rho_a\right]}\right]^{1/2} \qquad (20.50)$$

Measurements were made on beams of length 200 $\mu$m with varying values of $L_d$. The beam was excited strongly into resonance by a sinusoidal excitation which was tuned to get a large amplitude. The sinusoid was then turned off and the free oscillation was measured by sensing the diffracted signal. The resulting data were fitted to a damped sinusoid and the resonance frequency was extracted. As expected, the resonant frequency decreased with increasing $L_d$, consistent with a compressive stress on the aluminum. The fit of the frequency-*vs.*-$L_d$ data to the above expression permitted extraction of values of 801 ± 2 MPa for the tensile nitride stress, and -92 ± 8 for the compressive aluminum stress.[7] With these values in hand, it is possible to design the pixel to achieve a desired voltage-displacement characteristic.

[7]These values are the uniaxial stress values after release. Prior to release, the biaxial stress would be larger by a factor $1/(1-\nu)$.



### 20.4.3.4 Beam Curvature

We previously analyzed the diffraction assuming that the displaced beams were perfectly flat. In fact, though, the actuated beams bend, as illustrated in Fig. 20.20.

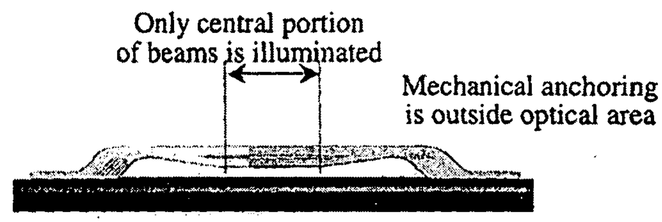


*Figure 20.20.* Illustrating the bending of GLV beams that occurs during actuation. Only the central portion of the beams is illuminated. [Source: Silicon Light Machines, reprinted with permission.]

In Eq. (20.19), we calculated the deflected shape of a GLV beam assuming perfectly clamped supports. In practice, the supports have finite compliance, but that is a second-order effect. Of more immediate interest is the effect of the beam curvature in the central illuminated portion of the deflected beam. For tension-dominated beams, the bending is nearly perfectly parabolic. We can calculate the radius of curvature from the expression

$$\hat{w} = Ax(L-x) \qquad (20.51)$$

The maximum deflection is at the center, and equals $AL^2/4$. In use, this maximum deflection is $\lambda/4$. Thus, in use, the largest value of $A$ is $\lambda/L^2$. The radius of curvature is $1/2A$. Hence, the most curvature and correspondingly smallest radius of curvature is $L^2/2\lambda$. If we use 650 nm as a typical wavelength, and 200 $\mu$m as a typical beam length, we estimate the smallest radius of curvature as 3 cm.

If all of the beams, including the reference beams, were similarly curved, then the effect of the curvature would be to focus the diffracted waves. However, the reference beams remain flat, and most of the time, most of the bent beams are deflected far less than the maximum and hence have much larger radii of curvature. This may explain the fact that the curvature of the deflected beams does not appear to create any significant artifact in the projected image [122].

### 20.4.3.5 Voltage-Intensity Characteristic

We can now assemble the pieces. Substituting $p = 1$ into Eq. (20.49), corresponding to a fully coated beam, and using the extracted stress values for the individual films, the material densities ($\rho_a$ = 2700 kg/m$^3$, $\rho_n$ = 3440 kg/m$^3$), elastic moduli ($E_a$ = 70 GPa, $E_n$ = 250 GPa), and film thicknesses ($h_a$